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Title:

Evolution of tetraploid wheat based on variations in 5´ UTR regions of *Ppd-A1*: evidence of gene flow between emmer and timopheevi wheat

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Abstract:

Previous study showed that tetraploid wheat was divided into two groups (Type AI and Type

AII) based on sequences around *Ppd-A1* gene (Takenaka and Kawahara 2012). That study focused on domesticated emmer wheat and used only 19 wild emmer wheat, so could not be clear the evolutional relationship between Type AI and Type AII. Here, a total of 669 accessions comprising 65 einkorn wheat, 185 wild emmer wheat, 107 hulled emmer wheat, 204 free-threshing (FT) emmer wheat, and 108 timopheevii wheat were studied by PCR assay and DNA sequencing for Type AI/AII. Type AII was an older type than Type AI because all einkorn accessions had Type AII. In wild emmer, Type AI was distributed in the northeast regions of its distribution and Type AII was found to be centered on Israel. A total of 37.4% of hulled emmer accessions were Type AI, while 92.2% of FT emmer accessions were Type AI. Differences in the proportion of Type AI/AII in domesticated emmer suggested a strong bottle-neck effect. We also found two MITE-like sequence deletion patterns from a part of Type AII accessions (dic-del and ara-del). Dic-del was found from only Israeli wild emmer accessions and ara-del was found from almost all timopheevii wheat accessions. Only three timopheevii accessions did not have ara-del, and one wild emmer accession and ten hulled emmer accessions had ara-del. These accessions suggested gene flow between emmer and timopheevii wheat.

Key Words:

tetraploid wheat, Ppd-1, domestication, evolution, gene flow

Introduction

Wheat is the one of the most important staple crops and is cultivated all over the world. Today, it accounts for more than 20% of total human food calories (faostat.fao.org). There is an urgent need to improve wheat for sustainable production in response to an explosion in world population and global climate change (wheat.org). For wheat breeding to satisfy such requirements, the genetic diversity of wild relatives and wheat landraces adapting to various environment is very important as genetic resources (Harlan 1975).

The genus *Triticum* L. consists of diploid einkorn wheat (2n = 14, AA), tetraploid emmer (2n = 28, BBA^uA^u) and timopheevii wheats (GGA^uA^u), and hexaploid common wheat (2n = 42, $DDBBA^uA^u$) (for a review, see Lilienfeld 1951). Tetraploid wheats originated independently by hybridization and amphiploidization between *Aegilops speltoides* (SS) (or a genotype similar to it) as the female parent and *T. urartu* (A^uA^u) as the male parent (Hori and Tsunewaki 1967; Maan and Lucken 1971; Ogihara and Tsunewaki 1982; Dvořák *et al.* 1993; Tsunewaki 2009). The hybridization that generated wild emmer wheat (*T. dicoccoides*) may have occurred between 0.25 to 1.3 Mya ago (Mori *et al.* 1995; Huang *et al.* 2002), while the hybridization that led to wild timopheevii wheat (*T. araraticum*) is likely to have occurred later (Mori *et al.* 1995; Brown-Guedira *et al.* 1996; Rodriguez, Perera *et al.* 2000; Huang *et al.* 2002; Kilian *et al.* 2007). Wild emmer wheat was domesticated in the Levant (southeastern Turkey to Syria) about 10,000 years before present (BP) (Nesbitt and Samuel 1998; Özkan *et al.* 2002, 2005; Mori *et al.* 2003; Tanno and Willcox 2006; Luo *et al.* 2007; Dubcovsky and Dvorake 2007). As an important component of the West Asian agriculture complex, domesticated hulled emmer (*T. dicoccon etc.*) spread throughout the world (Bellwood 2005; Luo *et al.* 2007). By about 8,500 years BP, hulled emmer wheat with tough glumes had evolved to free-threshing (FT) emmer wheat (*T. durum etc.*) (Salamini *et al.* 2002). Wild timopheevii wheat was also domesticated in southern Turkey and northern Syria (Mori *et al.* 2009).

However, unlike emmer wheat, domesticated timopheevii wheat (*T. timopheevii*) is an endemic crop restricted to western Georgia in Transcaucasia (Zohary and Hopf 2000).

Our previous study shows that emmer wheat is divided into two groups (Type AI and Type AII) based on about 200 bp sequences, which are around 1 kbp upstream of the *Ppd-A1* gene and include insertion/deletion mutations (Fig. 1, Takenaka and Kawahara 2012). Some hulled emmer wheat of Type AII are devoid of about 100 bp of MITE-like sequences (Type AIIa). They also report that in domesticated emmer, less than half of hulled emmer (44.4%) are Type AI and most FT emmer (94.7%) are Type AI and Type AII FT emmer are restricted to former Yugoslavian countries, while in wild emmer, Type AI are distributed in Turkey, Iran, Iraq, and Israel and Type AII are distributed in Israel, Syria, and Turkey. That study focused on domesticated emmer and used only 19 wile emmer accessions, so could not clarify the evolution of emmer wheat. In this paper, we focus on the regions dividing Type AI and Type AII, and the deletion pattern of MITE-like sequences. We also discuss the evolution of tetraploid wheats using more wheat accessions than the previous study.

Materials and Methods

Plant Materials

A total of 669 accessions of wheat comprising 185 wild emmer wheat (*Triticum dicoccoides* (Körn. ex Asch. et Graebn.) Schweinf.), 107 domesticated hulled emmer wheat (*T. dicoccon* Schrank, *T. karamyschevii* Nevski and *T. ispahanicum* Heslot), 204 domesticated free-threshing (FT) emmer wheat (*T. durum* Desf., *T. turgidum* L. s. str., *T. polonicum* L., *T. carthlicum* Nevski, *T. turanicum* Jakubz., *T. aethiopicum* Jakubz. and *T. pyramidale* (Del.) Perc.), 103 wild timopheevii wheat (*T. araraticum* Jakubz.), 5 domesticated timopheevii wheat (*T. timopheevii* (Zhuk.) Zhuk. s. str.), 60 wild einkorn wheat (*T. boeoticum* Boiss. and *T. urartu* Thum. ex Gandil.), and 5 domesticated einkorn wheat (*T. monococcum* L.)

were used (Table S). A total of 158 accessions had been analyzed by Takenaka and Kawahara (2012), of which 19 were wild emmer wheat accessions, 45 hulled emmer wheat accessions, and 94 FT emmer wheat accessions. Sixty-seven wild emmer accessions had been analyzed by Özkan *et al.* (2011). These accessions were maintained at National BioResources Project KOMUGI (Laboratory of Crop Evolution, Graduate School of Agriculture, Kyoto University) and USDA. Seeds of 12 wild timopheevii accessions were kindly provided by Dr. Sasanuma, Yamagata University, Japan and Dr. Mori, Kobe University, Japan. In this paper, the nomenclature and genome formula is followed from Hammer et al. (2011) and the Catalogue of NBRP KOMUGI with little changes.

PCR assays for Type AI and Type AII

Total DNA was extracted from young leaves from each accession by the CTAB method (Escaravage *et al.* 1998). Extracted DNA was stored in 100 μL of TE buffer at 4°C. DNA was amplified by PCR using specific primers for Type AI and Type AII, which corresponded to Type AI and Type AII and produced a band (Takenaka and Kawahara 2012). PCR amplification involved 50 ng of template DNA, 1 μM each primer, 1.5 mM $MgCl_2$, 0.2 mM dNTPs, 1.5 μL of 10×PCR Buffer (TaKaRa, Japan), and 0.5 U of *Taq* Polymerase (TaKaRa, Japan) in a total volume of 15 μL. Amplification conditions were 96°C for 2 min followed by 30 cycles of 96°C for 20 sec, 62°C for 20 sec, and 72°C for 30 sec. PCR products were separated on 2% agarose gels in TAE buffer.

DNA Sequencing

All accessions that were divided into Type AIIa by PCR assays were sequenced and the deletion pattern of MITE-like sequences was checked. PCR amplification involved 50 ng of template DNA, 1 μM each primer (up A F9: aacaacgagcatggacgagac, up_A_R600: ctggatccgcatatcttttctc), 0.2 mM dNTPs, 2 μL of 10×*Ex Taq* Buffer (TaKaRa, Japan), 0.6 μL of DMSO, and 0.5 U of *TaKaRa Ex Taq* HS (TaKaRa, Japan) in a total volume of 20 μL. Amplification conditions were 30 cycles of 98°C for 10 s, 62°C for 15 s, and 72°C for 2 min. PCR products were cleaned using the AMPure® kit (Bio Medical Science, Tokyo, Japan). The BigDye Terminator v3.1 Cycle Sequencing® kit (Applied Biosystem, Tokyo, Japan) and a primer (up_A_R601: cgcatatcttttctcctctcc) were used for sequencing reactions. Sequencing reaction products were cleaned using CleanSEQ® (Applied Biosystem, Tokyo, Japan) and sequenced using an ABI PRISM® 3100 Genetic Analyzer. The primers used for PCR amplification and sequencing, designed for use with primer 3 (Rozen and Skaletsky 2000), were based on sequence data from the DDBJ website (http://www.ddbj.nig.ac.jp/). The sequence data from *Ppd-A1*, *Ppd-B1*, and *Ppd-G1* and their adjacent regions were obtained from a total of 77 accessions (5 wild emmer wheat, 9 hulled emmer wheat, 2 FT emmer wheat, 10 wild timopheevii wheat, 5 domesticated timopheevii wheat, 43 wild einkorn wheat, and 3 domesticated einkorn wheat, table S) according to a previous study (Takenaka and Kawahara 2012).

Data analyses

Sequences were manually inspected with BioEdit ver. 7.0.9 (Hall 1999) and alignments were generated with MAFFT v6.846b (Kato and Toh 2008). The sequence data from 5' UTR, intronic, coding, and 3' UTR regions of *Ppd-A1* and intronic and coding regions of *Ppd-B1* and *Ppd-G1* were analyzed for phylogenetic relationships by the neighbor-joining (NJ) method (Saitou and Nei 1987) using MEGA ver. 5.0 (Tamura *et al.* 2011). Evolutionary distances were computed using the Kimura 2-parameter method (Kimura 1980) and all positions containing alignment gaps and missing data were eliminated only in pairwise sequence comparisons. The percentage of replicate trees in which associated haplotypes clustered together was calculated in the bootstrap test (1,000 replicates). Haplotypes based on sequencing data of *Ppd-1* genes (cording and intronic regions) were scored with DnaSP ver. 5.1 (Librado and Rozas

2009) and Median-Joining (MJ) networks (Bandelt *et al.* 1999) were constructed with the Network 4.610 program (Fluxus Technology Ltd, Clare, Suffolk, UK). GenBank sequencing accessions analyzed in this study were AB691782–AB691938, AB693038, AB692786–AB692942, AB693039 (Takenaka and Kawahara 2012), and AB745510-AB745620 (sequenced in this study).

Results

PCR assay for Type AI / Type AII and their geographical distribution

All diploid species (*T. boeoticum*, *T. monococcum*, and *T. urartu*) and timopheevii wheat (*T. araraticum* and *T. timopheevii*) were Type AII. Type AI was found only in emmer wheat (Table 1). In wild emmer wheat, 82 accessions (44.3%) were Type AI. Type AI wild emmer wheat was distributed across a wide range. In particular, central-eastern wild emmer accessions were all Type AI. On the other hand, Type AII wild emmer accessions were distributed centering on Israel (Fig. 2a). In hulled emmer wheat, 67 accessions (62.6%) were Type AII (Table 2). Both Type AI and Type AII were widely distributed in the collection area. However, many accessions of Type AI were spread on the western side centered on Europe, and many accessions of Type AII were spread on the eastern side centered on the Middle East (Fig. 2b). In FT emmer wheat, 188 accessions (92.2%) were Type AI and a few FT emmer accessions of Type AII were distributed centering on Former Yugoslavian countries (Table 2 and Fig. 2c). We could not identify two FT emmer accessions (PI244061 and KU-146) by the PCR assay for Type AI / Type AII because they had a GS-105-type deletion (Fig. 1 and Table 2) (Wilihelm *et al.* 2009).

The deletion patterns of MITE-like sequences found in Type AII accessions

In the PCR assay, a small band was produced from some accessions of Type AII. The small band was caused by a deletion (*ca.* 100 bp) of MITE-like sequences. This deletion was mentioned as Type

AIIa in a previous study (Takenaka and Kawahara 2012). In this study, we found that there were two deletion patterns based on sequencing data. Differences in deletion patterns were shown in Fig. 1. One type of deletion was found in most timopheevii wheat, so we named it as araraticum-type-deletion (ara-del). The other type of deletion was found only in wild emmer wheat, so we named it as dicoccoides-type-deletion (dic-del). Dic-del was found in 32 wild emmer accessions in Israel (Fig. 2a,b and Table 3). On the other hand, ara-del was found from most wild timopheevii accessions (100 accessions, 97.1%), all domesticated timopheevii accessions, one wild emmer accession (KU-14531), and ten hulled emmer accessions (*T. dicoccon*; PI94633, PI94663, PI254177, PI254189, PI 272533, KU-1533, KU-1538, and KU-3371, *T. ispahanicum*; KU-145 and KU-4580). Only three wild timopheevii accessions (KU-1943, KU-1990, and IG 116177) did not have ara-del and were all found in Turkey.

Sequence diversity and phylogenetic analysis

Genetic relationships among accessions are shown by an NJ tree based on all sequence data (5' UTR , intronic, cording, and 3' UTR regions of *Ppd-A1*, Fig. 3). Accessions were divided into three clades. The first clade was constituted by the A^m genome diploid species (*T. boeoticum* and *T. monococcum*), the second one was constituted by the A^u genome diploid species (*T. urartu*), and the third one was constituted by tetraploid wheat (BBAA and GGAA genome species).

The A^m genome clade was divided into two groups. One group contained only *T. boeoticum* and another group included both *T. boeoticum* and *T. monococcum* (Fig. 3). The two groups in the A^m genome clade were divided based on some SNPs and three insertion/deletion mutations (14bp, 177bp, and 23bp), which were all found in the 5' UTR region of *Ppd-A1* (23bp insertion mutations are shown in Fig. 1). In *Ppd-A1* cording and intronic regions, no mutation specific for each group was found.

The A^u genome clade was also divided into two groups. The genetic distance between the two groups of the A^u genome clade was smaller than the distance between the two groups of the A^m genome clade (Fig. 3). The two groups were divided based on some SNPs, which were all found in the 5' UTR region of *Ppd-A1*. One 9 bp deletion (CCA repeats), which was specific for one group, was found in the 1st exon.

The tetraploid wheat clade was divided into two sub-clades. The GGAA genome sub-clade included most GGAA genome accessions and all BBAA genome accessions with ara-del. The BBAA genome sub-clade consisted of most BBAA genome accessions and *T. araraticum* accessions (KU-1943 and IG 116177), which do not have ara-del. Wild emmer accessions with dic-del and Type AI emmer accessions formed distinct groups in the BBAA genome sub-clade (Fig. 3).

There were 65 SNPs and insertion/deletion variants in *Ppd-A1* cording and intronic regions of tetraploid wheat. Ten polymorphic sites were specific each for timopheevii wheat (excluded accessions without ara-del) or emmer wheat (excluded accessions with ara-del). Emmer wheat that had ara-del was shared in seven polymorphic sites with timopheevii wheat, and timopheevii wheat without ara-del shared these with most emmer wheat (Table 4).

Even when the haplotype network based on *Ppd-A1* was constructed, three main clades of *Ppd-A1* were also formed (Fig. 4a). However, in the BBAA sub-clade, the distinction between Type AI and Type AII disappeared. As different from the *Ppd-A1* haplotype network, there were many differences between *Ppd-B1* of emmer wheat and *Ppd-G1* of timopheevii wheat (Fig. 4b). Unlike the phylogenetic tree based on *Ppd-A1*, all hulled emmer wheat with ara-del was included in the *Ppd-B1* group. *T. araraticum* accessions without ara-del were also included in the *Ppd-B1* group. On the other hand, one wild emmer accession with ara-del (KU-14531) was included in the *Ppd-G1* group (Fig. 4b).

Discussion

Evolution of emmer wheat based on Type AI and Type AII

In wild emmer wheat, both Type AI and Type AII existed but all diploid species were Type AII (Table 1). The phylogenetic tree based on *Ppd-A1* shows that all Type AI accessions are monophyletic (Fig. 3). These results suggest that Type AII is an older type than Type AI and that the Type AI line was derived partially from Type AII lines. Most Type AI wild emmer wheat was found in central-eastern parts of distributions and Type AII wild emmer wheat was found in western parts of distributions centering on Israel (Fig. 2a). This suggests that characteristic mutations of Type AI occurred in central-eastern wild emmer wheat. Luo *et al.* (2007) and Özkan *et al.* (2005 and 2011) showed that wild emmer is divided into central-eastern and western lines and that central-eastern one contributed to domestication. Sixty-seven wild emmer accessions used in this study were typed by Özkan *et al.* (2011) based on ALFP analysis (Table 5 and Table S). Accessions typed as Ib, Ic, and III by Özkan *et al.* (2011) were all Type AI and accessions typed as V were all Type AII with dic-del. Accessions typed as II and IV were both Type AI and Type AII (Table 5). Özkan *et al.* (2011) defined groups I, II and III as central-eastern wild emmer lines and groups IV and V as western wild emmer lines. ALFP analysis detects variations in the whole genome but our study targeted variations that existed in very limited regions. Because of this difference, these results did not correspond completely. However, the differences between Type AI and Type AII may show the differences between central-eastern and western wild emmer. Therefore, we thought that Type AI domesticated hulled emmer was directly domesticated from Type AI wild emmer lines and that Type AII domesticated hulled emmer was not domesticated from Type AII wild emmer lines, but rather arouse by introgression between domesticated emmer and Type AII wild emmer around Israel. The introgression between hulled emmer and wild emmer in Israel has already reported (Luo *et al.* 2007). Our previous study dealing with this problem had used only 19 wild emmer accessions (Takenaka and Kawahara 2012), but here we used 185 wild emmer accessions, which further supported the results.

More than half of hulled emmer accessions (62.6%) were Type AII (Table 2). This suggested that the introgression between domesticated emmer and Type AII wild emmer occurred at an early stage of evolution and diffusion of hulled emmer wheat. Different from hulled emmer, most accessions of free-threshing (FT) emmer were Type AI (92.2%, Table 2). Type AII FT emmer accessions were rare, but they were distributed in wide areas (Iran, Turkey, Bosnia and Herzegovina, Croatia, Macedonia, Montenegro, Spain, Portugal, and Algeria, Fig. 2c). In Turkey and Iran, there were both Type AII hulled emmer accessions and Type AII FT emmer accessions (Fig. 2b,c). Therefore, Type AII FT emmer may be evolved from Type AII hulled emmer in these regions. On the other hand, we could not find Type AII hulled emmer accessions from other regions where Type AII FT emmer accessions grow. These Type AII FT emmer accessions may have arisen in each region independently or may have been derived from other regions (*e.g.* Turkey and Iran). More research on this unique type of emmer is needed. Whether Type AII FT emmer races were of single origin or multiple origins, the result that almost all FT emmer accessions were Type AI suggested a strong bottleneck effect for domesticated emmer. As the result of this strong bottleneck effect, we could not fully apply the genetic resources of Type AII emmer for wheat cultivated today.

Evolution of tetraploid wheat based on deletion patterns of MITE-like sequences

Type AII accessions with dic-del were found only from wild emmer wheat in Israel (Fig. 2a). This suggested that dic-del was a specific variation for wild emmer in Israel and that wild emmer with dic-del have not influenced domesticated emmer wheat. Therefore, wild emmer accessions with dic-del would contribute greatly as genetic resources of domesticated emmer wheat.

Almost all timopheevii wheat having ara-del (Table 3) suggested that this mutation occurred in timopheevii wheat soon after it arrived or in ancestral diploid species, which donated A genomes to timopheevii wheat, and that this mutation was specific for timopheevii wheat. In this study, we found ten hulled emmer accessions with ara-del. This indicated that ara-del, which was found in hulled emmer wheat, was derived from timopheevii wheat. Phylogenetic trees, MJ networks, and SNPs information based on *Ppd-A1* gene regions also supported that the regions of ten hulled emmer wheat accessions originating from timopheevii wheat (Fig. 3, 4a and Table 4). MJ networks based on *Ppd-B1*/*Ppd-G1* showed that ten hulled emmer wheat accessions with ara-del had not *Ppd-G1* but *Ppd-B1* (Fig. 4b). Their morphological appearances were also accorded with emmer wheat. Moreover, previous studies had treated some hulled emmer accessions with ara-del as emmer wheat and these studies did not report that these accessions had the characteristics of timopheevii wheat (Mori *et al.* 1997; Ishii *et al.* 2001; Asakura *et al.* 2001; Hirosawa *et al.* 2004). Thus, we thought that these ten hulled emmer accessions with ara-del originated from introgression from timopheevii wheat and that chromosome substitution occurred at regions including the *Ppd-A1* gene. *T. araraticum* distributed from the east side of the Fertile Crescent to Transcaucasia, and most hulled emmer accessions with ara-del were found in this region (Iran and Georgia, Fig. 2b). In these regions, populations of *T. araraticum* were colonized as a weed in fields of emmer wheat (Nesbitt and Samuel 1996). Such a situation had chances of interspecific crossing between emmer wheat and weed timopheevii wheat. Because of hybrid sterility, their F_1 usually could not leave F_2 generations (Tanaka *et al.* 1979). Hybrid sterility, however, recovered when F_1 hybrids were backcrossed (Maan 1972). In fields of emmer wheat, successive backcrossing with emmer wheat could cause hulled emmer wheat that has part of the timopheevii wheat chromosome. Hulled emmer accessions with ara-del were also found in Europe and North Africa (Hungary, Germany, and Morocco) where timopheevii wheat did not distribute (Fig. 2b). This suggested that hulled emmer wheat, which originated around Transcaucasia, was introduced into Europe and North Africa, via the northern shore of the Black Sea and through the Strait of Gibraltar.

One wild emmer accession in Israel (KU-14531) also had ara-del and MJ networks based on *Ppd-B1*/*Ppd-G1* showed that this accession did not have *Ppd-B1* but *Ppd-G1* (Fig. 4b). This may indicate that the accession was not *T. dicoccoides* but *T. araraticum*. However, *T. araraticum* was not found in Israel where the accession came from, and morphological characteristics showed that the accession was *T. dicoccoides*. We need to perform more research on this accession.

Three *T. araraticum* accessions (KU-1943, KU-1990 and IG116177) did not have ara-del and a phylogenetic tree based on *Ppd-A1* regions showed that these accessions were included in the BBAA genome sub-clade (Fig. 3). In addition, MJ networks based on *Ppd-B1*/*Ppd-G1* showed that these accessions were included in the *Ppd-B1* group (Fig. 4b). These results may suggest that these *T. araraticum* accessions were not timopheevii wheat but emmer wheat. These accessions had been analyzed as wild timopheevii wheat for RFLP analyses by Mori *et al.* (1995), SSLP by Ishii *et al.* (2001), and chloroplast DNA fingerprinting by Mori *et al.* (2009). These results and the morphological characteristics of these *T. araraticum* accessions showed that the accessions were timopheevii wheat. All *T. araraticum* accessions without MITE-like sequence deletions were found from Southeast Turkey where there were mixed populations of *T. dicoccoides* and *T. araraticum* (Nesbitt and Samuel 1996). In addition, some *T. dicoccoides* lines in Turkey produced hybrids with fertility when crossed with *T. araraticum* (Rawal and Harlan 1975). Thus, we thought that these *T. araraticum* accessions without MITE-like sequence deletions had originated from interspecific crossing with *T. dicoccoides* and that chromosome substitutions occurred at regions including both *Ppd-A1* and *Ppd-G1* genes.

Hulled emmer wheat with ara-del and wild timopheevii wheat without MITE-like sequence deletions particularly showed that the gene flow between emmer wheat and timopheevii wheat occurred and that timopheevii wheat, which was of a different linage to emmer and common wheat, also had important genetic resources for wheat breeding.

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Figure Legends

Fig. 1 Consensus sequences around MITE-like deletions. Gray parts show unique sequences of Type AI/AII and ara-del/dic-del. ① Type AI including 10 wild emmer, 23 hulled emmer, and 90 FT emmer accessions ② Type AI including 4 wild emmer accessions. ③ Type AII including 4 *T. boeoticum* accessions. ④ Type AII including 2 *T. boeoticum* and 3 *T. monococcum* accessions. ⑤ Type AII with dic-del including 4 wild emmer accessions. ⑥ Type AII with ara-del including 1 wild emmer, 10 hulled emmer, and 13 timopheevii accessions. ⑦ Type AII without MITE-like sequence deletions including 37 *T. urartu,* 8 wild emmer, 21 hulled emmer, 4 FT emmer, and 2 wild timopheevii accessions. ⑧ GS-105 deletion including 2 FT emmer accessions.

Fig. 2 Geographical distribution of Type AI and Type AII emmer accessions. Only the ratio of each type is shown. (a) Distribution of wild emmer accessions shown by collected regions. (b) Distribution of hulled emmer accessions shown by collected countries. (c) Distribution of FT emmer accessions shown by collected countries.

Fig. 3 Neighbor-joining phylogenetic tree built with the 5’ UTR, intronic, coding, and 3’ UTR regions of *Ppd-A1*. Bootstrap values (1,000 replicates, more than 80) are shown next to the branches. Analyses include 233 accessions. Type AI emmer, partial Type AII emmer, Type AII emmer with dic-del and diploid accessions are compressed.

Fig. 4 MJ networks derived from DNA sequence haplotypes among accessions. (a) Haplotypes of *Ppd-A1*. (b) Haplotypes of *Ppd-B1* and *Ppd-G1*. Black part, gray part, hatched part on white background, and hatched part on gray background show emmer wheat, timopheevii wheat, the A^{u} genome species (*T. urartu*), and A^{m} genome species (*T. boeoticum* and *T. monococcum*). A small white circle means a substitution and many substitutions are shown by figures.

Table 1 The number of accessions divided by collected countries, excluding domesticated emmer.

Species (genome)	Country	Type AI		Type AII		total
		n	%	n	%	
T. urartu (A^uA^u)	Iran	0	0.0	2	100.0	2
	Lebanon	0	0.0	10	100.0	10
	Turkey	0	0.0	21	100.0	21
	USSR	0	0.0	4	100.0	4
	total	0	0.0	37	100.0	37
T. boeoticum (A^mA^m)	Greece	0	0.0	1	100.0	1
	Iran	0	0.0	2	100.0	2
	Iraq	0	0.0	5	100.0	5
	Turkey	0	0.0	14	100.0	14
	USSR	0	0.0	1	100.0	1
	total	0	0.0	23	100.0	23
T. monococcum (A^mA^m)	Romania	0	0.0	1	100.0	1
	Spain	0	0.0	1	100.0	1
	Turkey	0	0.0	1	100.0	1
	unknown	0	0.0	2	100.0	2
	total	0	0.0	5	100.0	5
T. araraticum (GGA^uA^u)	Iran	0	0.0	4	100.0	4
	Iraq	0	0.0	65	100.0	65
	Syria	0	0.0	3	100.0	3
	Turkey	0	0.0	27	100.0	27
	USSR	0	0.0	4	100.0	4
	total	0	0.0	103	100.0	103
T. timopheevii (GGA^uA^u)	Turkey	0	0.0	1	100.0	1
	USSR	0	0.0	1	100.0	1
	unknown	0	0.0	3	100.0	3
	total	0	0.0	5	100.0	5
T. dicoccoides (BBA^uA^u)	Iran	4	100.0	0	0.0	4
	Iraq	22	100.0	0	0.0	22
	Israel	39	28.9	96	71.1	135
	Syria	1	50.0	1	50.0	2
	Turkey	14	73.7	5	26.3	19
	unknown	2	66.7	1	33.3	3
	total	82	44.3	103	55.7	185

Table 2 The number of domesticated emmer accessions divided by PCR assays.

Grain	Species	Type AI		Type AII		GS-105		total
		n	%	n	%	n	%	
Hulled	*T. dicoccon*	38	36.9	65	63.1	0	0.0	103
	T. ispahanicum	0	0.0	2	100.0	0	0.0	2
	T. karamyschevii	2	100.0	0	0.0	0	0.0	2
	total	40	37.4	67	62.6	0	0.0	107
FT	*T. durum*	116	92.1	9	7.1	1	0.8	126
	T. turgidum	18	78.3	5	21.7	0	0.0	23
	T. polonicum	11	100.0	0	0.0	0	0.0	11
	T. turanicum	13	100.0	0	0.0	0	0.0	13
	T. carthlicum	8	100.0	0	0.0	0	0.0	8
	T. aethiopicum	21	100.0	0	0.0	0	0.0	21
	T. pyramidale	1	50.0	0	0.0	1	50.0	2
	total	188	92.2	14	6.9	2	1.0	204

*GS-105: 1017bp of deletion (Wilihelm *et al.* 2009)

Table 3 The number of Type AII tetraploid wheat accessions divided by MITE-like sequence deletion patterns.

	non del*	dic-del	ara-del	total
T. dicoccoides	70	32	1	103
T. dicoccon	57	0	8	65
T. ispahanicum	0	0	2	2
T. durum	9	0	0	9
T. turgidum	5	0	0	5
T. araraticum	3	0	100	103
T. timopheevii	0	0	5	5
total	144	32	116	292

*non-del: Type AII accessions without MITE-like sequences deletion.

Table 4 *Ppd-A1* gene sequence polymorphisms in emmer and timopheevii wheat.

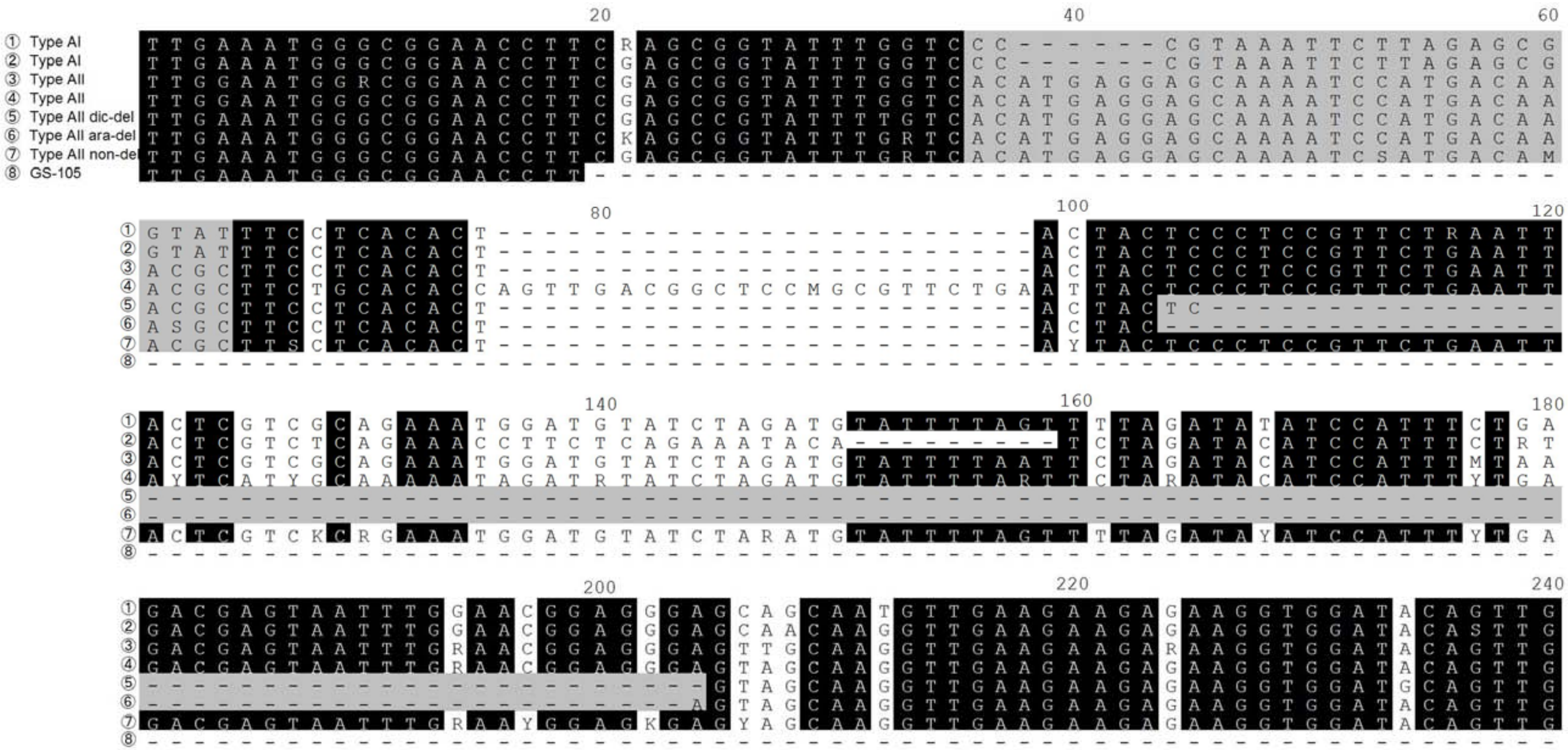
			emmer					timopheevii		
						Type AII				
Polymorphism	Position relative to Chinese Spring (DQ885753)	Chinese Spring	Type AI	no MITE-like del	dic-del	ara-del (wild emmer)	ara-del (hulled emmer)	no MITE-like del	ara-del (wild)	ara-del (domesticated)
1	7460 SNP, exon 1	C	C	C	C	G	C	C	G	C
2	7463 SNP, exon 1	G	C/G	C/G	G	G	G	G	G	G
3	7466 SNP, exon 1	G	C/G	C/G	G	G	G	G	G	G
4*	7535 SNP, exon 1	G	G	G	G	C	C	G	C	C
5	7562 SNP, exon 1	C	C/T	C	C	C	C	C	C	C
6	7680 SNP, intron 1	G	G	A/G	G	G	G	A	G	G
7	7692 SNP, intron 1	G	G	C/G	G	G	G	G	G	G
8	7716 SNP, intron 1	T	T	T	T	T	T	T	C/T	T
9*	7725 indel, intron 1	T	T	T	T	-	-	T	-	-
10*	7747 SNP, exon 2	T	T	T	T	C	C	T	C	C
11	7777 SNP, exon 2	C	C	C	C	T	C	C	C/T	T
12*	7811 SNP, exon 2	G	G	G	G	A	A	G	A	A
13*	7813 SNP, exon 2	C	C	C	C	G	G	C	G	G
14	7861 SNP, exon 2	G	G	G	A/G	G	G	G	G	G
15	7892 SNP, exon 2	A	A/G	A	A	A	A	A	A	A
16	7919 SNP, intron 2	C	C	C	C	T	C	C	C	C
17	7926 SNP, intron 2	C	C	C	C	C	C/G	C	C	C
18	8062 SNP, exon 3	C	C/G	C/G	C	C	C	C	C	C
19	8166 SNP, intron 3	G	C/G	C/G	G	G	G	G	G	G
20	8213 SNP, intron 3	T	T	T	C/T	T	T	T	T	T
21	8281 SNP, intron 3	T	C/T	C/T	T	T	T	T	T	T
22	8503 indel, intron 4	--	T-	T-/--	--	--	--	--	TT	--
23	8504 indel, intron 4	T	T	T/-	T	T	-	-	T	T
24	8506 SNP, intron 4	T	G/T	G/T	T	T	T	T	T	T
25	8512 SNP, intron 4	T	G/T	T	T	T	T	T	T	T
26	8537 SNP, intron 4	C	C	C	C	C	T	C	C	C
27	8541 indel, intron 4	C	-	-	-	-	-	-	-	-
28	8578 SNP, intron 4	A	A/C	A/C	A	A	A	A	A	A
29	8642 SNP, intron 4	C	C	C	C	T	C/T	C	T	T
30	8696 SNP, intron 4	T	T	T	T	C	C/T	T	C	C
31	8711 SNP, intron 4	A	A	A	A/G	A	A	A	A	A
32	8716 SNP, intron 4	G	G	A/G	A/G	G	G	G	G	G
33	8760 SNP, intron 4	G	G	G	G	G	G	G	A/G	G
34	8823 SNP, intron 4	A	A	A/G	A	A	A	A	A	A

35	8876 SNP, intron 4	C	C/T	C/T	C	C	C	C	C	C
36	8909 SNP, intron 4	C	C/G	C/G	C	C	C	C	C	C
37	8910 SNP, intron 4	T	T	T	T	T	T	T	T	C
38	TE in intron 5	Yes	No	No	No	No	No	No	No	No
39*	10369 SNP, intron 5	C	C	C	C	A	A	C	A	A
40*	10650 SNP, exon 6	A	A	A	A	G	G	A	G	G
41	10727 SNP, exon 6	G	A/G	A/G	G	G	G	G	G	G
42	10791 SNP, exon 6	A	A/G	G	G	G	G	G	G	G
43	10818 SNP, exon 6	A	A/G	A/G	G	A	A	G	A	A
44	10872 SNP, intron 6	A	A/G	A/G	A	A	A	A	A	A
45	10874 SNP, intron 6	T	A/T	A/T	T	T	T	T	T	T
46	10878 SNP, intron 6	A	A	A/C	A	A	A	A	A	A
47	10889 SNP, intron 6	C	C/G	C/G	C	C	C	C	C	C
48	10896 SNP, intron 6	T	T	T	A/T	T	T	T	T	T
49	10974 SNP, exon 7	C	C/G	G	G	G	G	G	G	G
50	11013 SNP, exon 7	A	A/G	A/G	A	A	A	A	A	A
51	11053 SNP, exon 7	A	A	A	A	A	A/T	A	A	A
52	11066 SNP, exon 7	C	C	C	C/T	C	C	C	C	C
53	11081 SNP, exon 7	C	C	C	C	T	C	C	C/T	T
54	11120 SNP, exon 7	C	C	C	C	T	C	C	C/T	T
55	11210 SNP, exon 7	A	A	A/T	A	A	A	T	A	A
56	11225 SNP, exon 7	G	A/G	G	G	G	G	G	G	G
57	11320 SNP, exon 7	C	C/T	C/T	C	C	C	C	C	C
58	11381 SNP, exon 7	G	G	A/G	G	G	G	A	G	G
59	11612 SNP, intron 7	A	A	A/G	A	A	A	A	A	A
60	11630 SNP, intron 7	C	C	C/T	C	C	C	C	C	C
61	11632 SNP, intron 7	G	G	G	G	G	G	G	A/G	G
62	11647 SNP, intron 7	C	C	C	C	C	C	C	C/T	C
63	11656 SNP, intron 7	G	G	A/G	A/G	G	G	A	G	G
64	11670 SNP, intron 7	A	A	A	A	A	A	A	A/G	A
65	11707 SNP, intron 7	A	A	A/G	A/G	A	A	A	A	A
66	11725 SNP, exon 8	G	G	G	G	G	A/G	G	G	G

* polymorphic site shared by accessions with ara-del.

Table 5 The number of wild emmer accessions used in this study and typed by Özkan *et al.* (2011)

Type of wild emmer	Ib	Ic	II	III	IV	V	total
Type AI	6	11	10	12	8	0	47
Type AII non-del	0	0	5	0	9	0	14
Type AII dic-del	0	0	0	0	1	4	5
total	6	11	15	12	18	4	66



① Type AI
② Type AI
③ Type AII
④ Type AII
⑤ Type AII dic-del
⑥ Type AII ara-del
⑦ Type AII non-del
⑧ GS-105

Fig. 1

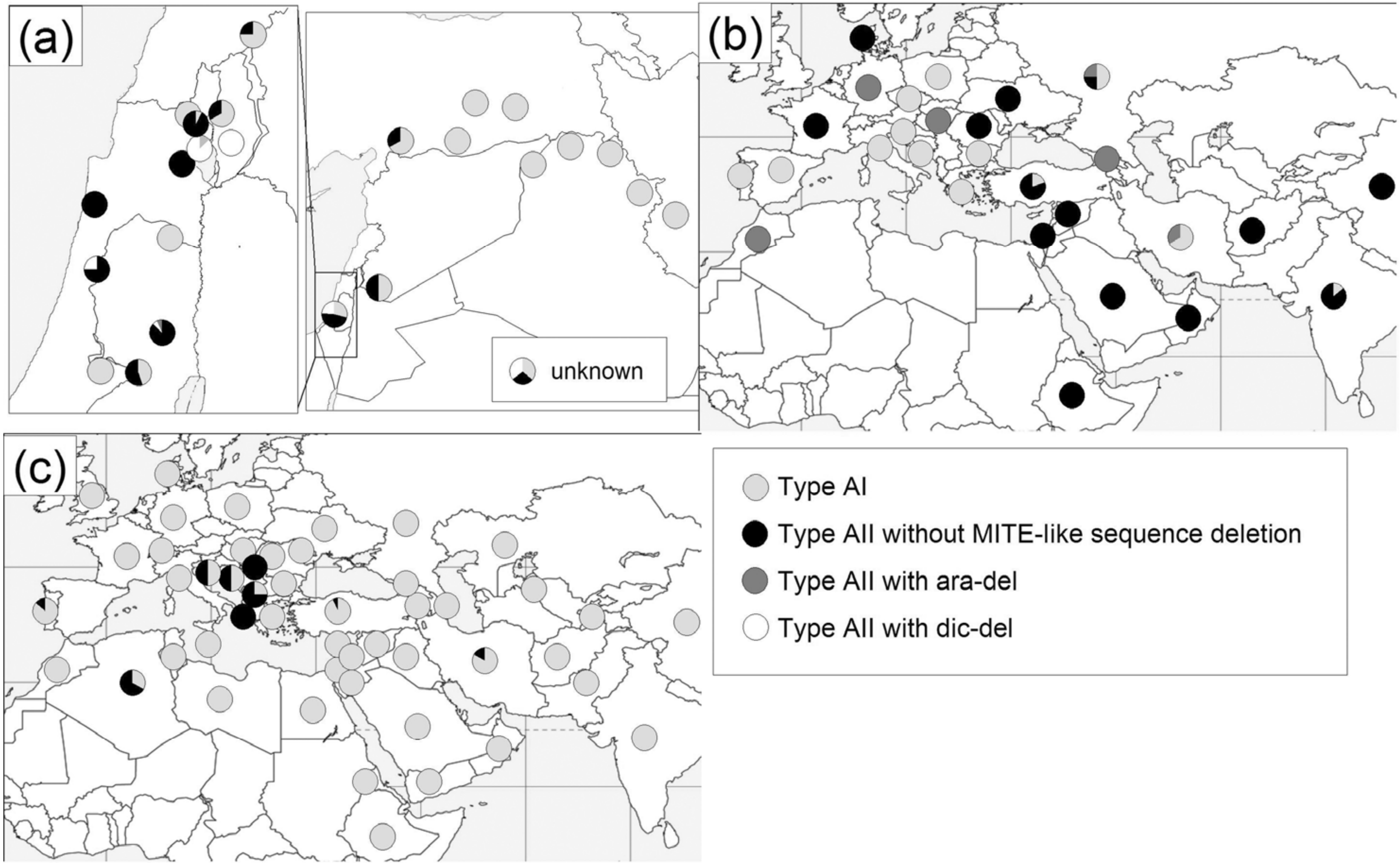
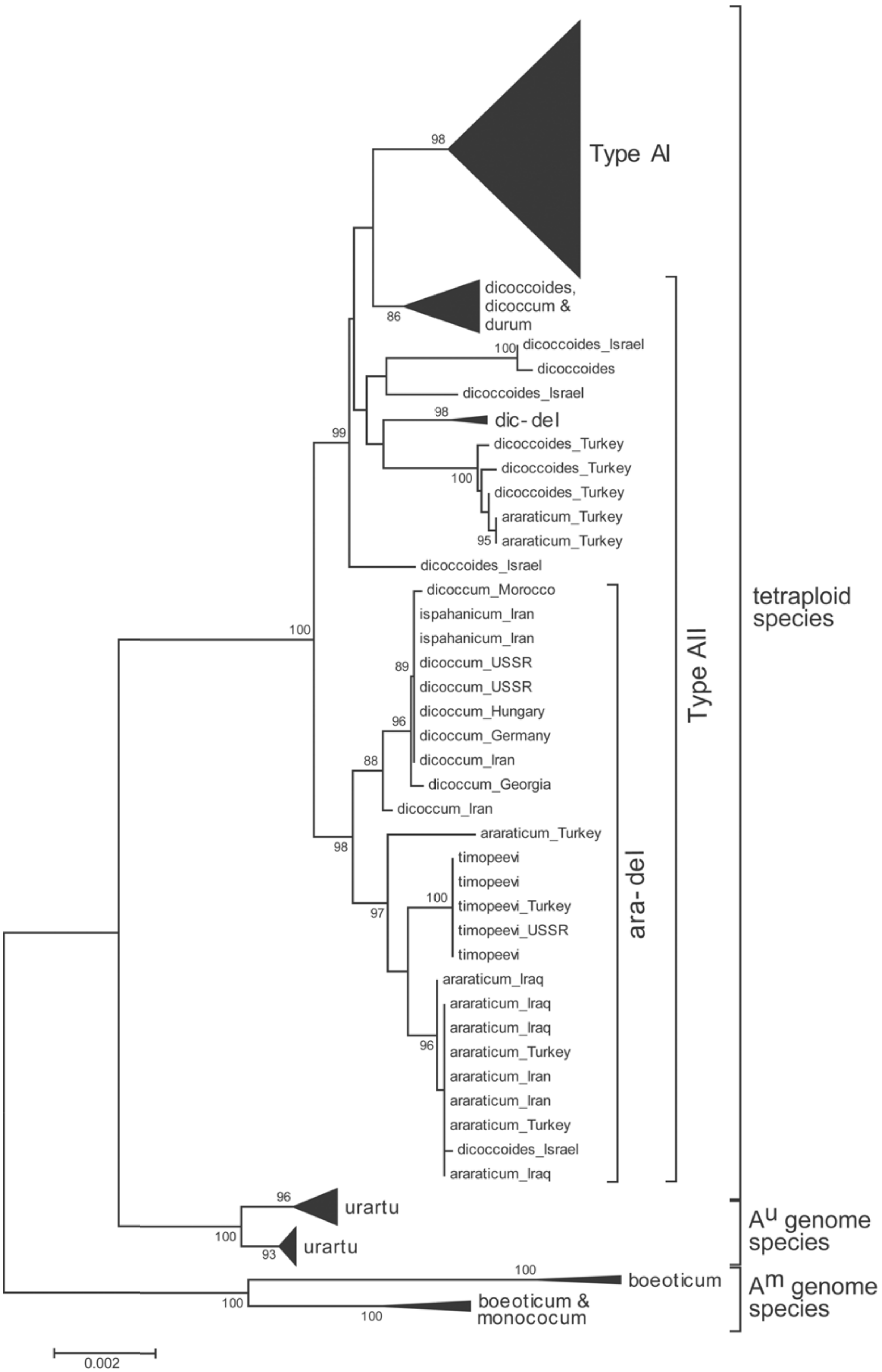

(a)
unknown
(b)
(c)
Type AI
Type AII without MITE-like sequence deletion
Type AII with ara-del
Type AII with dic-del

Fig. 2



98
Type AI
86
dicoccoides, dicoccum & durum
100
dicoccoides_Israel
dicoccoides
dicoccoides_Israel
98
dic-del
99
dicoccoides_Turkey
dicoccoides_Turkey
100
dicoccoides_Turkey
araraticum_Turkey
95
araraticum_Turkey
dicoccoides_Israel
dicoccum_Morocco
ispahanicum_Iran
ispahanicum_Iran
100
89
dicoccum_USSR
dicoccum_USSR
dicoccum_Hungary
96
dicoccum_Germany
88
dicoccum_Iran
dicoccum_Georgia
dicoccum_Iran
araraticum_Turkey
98
timopeevi
timopeevi
100
timopeevi_Turkey
97
timopeevi_USSR
timopeevi
araraticum_Iraq
araraticum_Iraq
araraticum_Iraq
96
araraticum_Turkey
araraticum_Iran
araraticum_Iran
araraticum_Turkey
dicoccoides_Israel
araraticum_Iraq
ara-del
Type AII
tetraploid species
96
urartu
100
93
urartu
A^u genome species
100
boeoticum
100
100
boeoticum & monococum
A^m genome species
0.002

Fig. 3

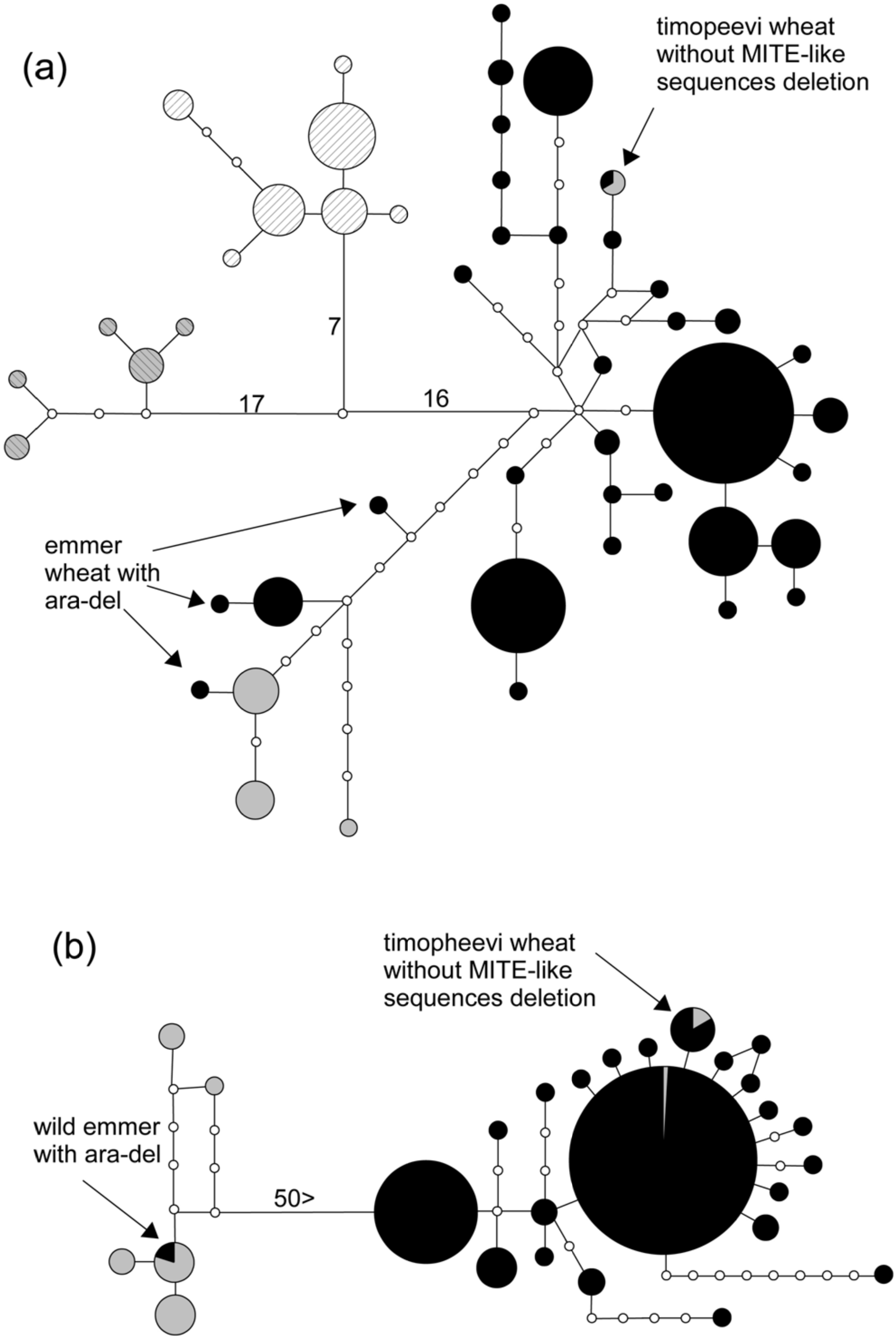

(a)
timopeevi wheat
without MITE-like
sequences deletion
7
17
16
emmer
wheat with
ara-del
(b)
timopheevi wheat
without MITE-like
sequences deletion
wild emmer
with ara-del
50>

Fig. 4

table S

AccessionNo.	Accession No.	Taxon	Country	Sequence	Typed in this stydy	Type by AFLP **
KU-101-2		*T. boeoticum*	USSR	Yes	AII non-del	-
KU-3601		*T. boeoticum*	Turkey	Yes	AII non-del	-
KU-3615		*T. boeoticum*	Turkey	No	AII non-del	-
KU-3630		*T. boeoticum*	Greece	Yes	AII non-del	-
KU-8026		*T. boeoticum*	Iraq	No	AII non-del	-
KU-8120		*T. boeoticum*	Iraq	Yes	AII non-del	-
KU-8128		*T. boeoticum*	Iraq	No	AII non-del	-
KU-8139		*T. boeoticum*	Iraq	No	AII non-del	-
KU-8223		*T. boeoticum*	Iraq	No	AII non-del	-
KU-8279		*T. boeoticum*	Turkey	Yes	AII non-del	-
KU-8307		*T. boeoticum*	Turkey	No	AII non-del	-
KU-8327		*T. boeoticum*	Turkey	No	AII non-del	-
KU-8358		*T. boeoticum*	Turkey	No	AII non-del	-
KU-8392		*T. boeoticum*	Iran	Yes	AII non-del	-
KU-8405		*T. boeoticum*	Iran	No	AII non-del	-
KU-10603		*T. boeoticum*	Turkey	No	AII non-del	-
KU-10653		*T. boeoticum*	Turkey	No	AII non-del	-
KU-10681		*T. boeoticum*	Turkey	No	AII non-del	-
KU-10773		*T. boeoticum*	Turkey	No	AII non-del	-
KU-10774		*T. boeoticum*	Turkey	No	AII non-del	-
KU-10834		*T. boeoticum*	Turkey	No	AII non-del	-
KU-10901		*T. boeoticum*	Turkey	No	AII non-del	-
KU-10908		*T. boeoticum*	Turkey	No	AII non-del	-
KU-104-2		*T. monococcum*	-	No	AII non-del	-
KU-104-4		*T. monococcum*	-	No	AII non-del	-
KU-1001		*T. monococcum*	Spain	Yes	AII non-del	-
KU-1404		*T. monococcum*	Romania	Yes	AII non-del	-
KU-3636		*T. monococcum*	Turkey	Yes	AII non-del	-
KU-199-1		*T. urartu*	USSR	Yes	AII non-del	-
KU-199-2		*T. urartu*	USSR	Yes	AII non-del	-
KU-199-3		*T. urartu*	USSR	Yes	AII non-del	-
KU-199-4		*T. urartu*	USSR	Yes	AII non-del	-
KU-199-5		*T. urartu*	Turkey	Yes	AII non-del	-
KU-199-6		*T. urartu*	Lebanon	Yes	AII non-del	-
KU-199-7		*T. urartu*	Lebanon	Yes	AII non-del	-
KU-199-8		*T. urartu*	Lebanon	Yes	AII non-del	-
KU-199-9		*T. urartu*	Iran	Yes	AII non-del	-
KU-199-10		*T. urartu*	Iran	Yes	AII non-del	-
KU-199-11		*T. urartu*	Turkey	Yes	AII non-del	-
KU-199-12		*T. urartu*	Turkey	Yes	AII non-del	-
KU-199-13		*T. urartu*	Turkey	Yes	AII non-del	-
KU-199-14		*T. urartu*	Turkey	Yes	AII non-del	-
KU-199-15		*T. urartu*	Lebanon	Yes	AII non-del	-
KU-199-16		*T. urartu*	Lebanon	Yes	AII non-del	-
KU-13336	PI 428200	*T. urartu*	Turkey	Yes	AII non-del	-
KU-13337	PI 428201	*T. urartu*	Turkey	Yes	AII non-del	-
KU-13338	PI 428206	*T. urartu*	Turkey	Yes	AII non-del	-
KU-13339	PI 428213	*T. urartu*	Turkey	Yes	AII non-del	-
KU-13340	PI 428214	*T. urartu*	Turkey	Yes	AII non-del	-
KU-13341	PI 428219	*T. urartu*	Turkey	Yes	AII non-del	-
KU-13342	PI 428220	*T. urartu*	Turkey	Yes	AII non-del	-
KU-13343	PI 428221	*T. urartu*	Turkey	Yes	AII non-del	-
KU-13344	PI 428221	*T. urartu*	Turkey	Yes	AII non-del	-
KU-13345	PI 428223	*T. urartu*	Turkey	Yes	AII non-del	-
KU-13346	PI 428223	*T. urartu*	Turkey	Yes	AII non-del	-
KU-13347	PI 428227	*T. urartu*	Turkey	Yes	AII non-del	-
KU-13348	PI 428245	*T. urartu*	Turkey	Yes	AII non-del	-
KU-13349	PI 428250	*T. urartu*	Turkey	Yes	AII non-del	-
KU-13350	PI 428252	*T. urartu*	Turkey	Yes	AII non-del	-
KU-13351	PI 428291	*T. urartu*	Lebanon	Yes	AII non-del	-
KU-13352	PI 428291	*T. urartu*	Lebanon	Yes	AII non-del	-
KU-13353	PI 428293	*T. urartu*	Lebanon	Yes	AII non-del	-

KU-13354	PI 428311	*T. urartu*	Lebanon	Yes	AII non-del	-
KU-13355	PI 428318	*T. urartu*	Turkey	Yes	AII non-del	-
KU-13356	PI 428319	*T. urartu*	Lebanon	Yes	AII non-del	-
KU-108-1		*T. dicoccoides*	-	No	AII dic-del	-
KU-108-2		*T. dicoccoides*	Syria	Yes*	AII non-del	IV
KU-108-3		*T. dicoccoides*	Syria	No	AI	IV
KU-108-4		*T. dicoccoides*	-	No	AI	-
KU-108-5		*T. dicoccoides*	-	Yes	AI	-
KU-109		*T. dicoccoides*	Israel	No	AI	-
KU-110		*T. dicoccoides*	Israel	No	AI	-
KU-195		*T. dicoccoides*	Israel	No	AII non-del	-
KU-198		*T. dicoccoides*	Israel	Yes*	AII non-del	-
KU-1921		*T. dicoccoides*	Turkey	Yes*	AI	II or III
KU-1945		*T. dicoccoides*	Turkey	Yes*	AII non-del	II
KU-1947		*T. dicoccoides*	Turkey	No	AI	II
KU-1948		*T. dicoccoides*	Turkey	No	AI	II
KU-1949		*T. dicoccoides*	Turkey	No	AII non-del	II
KU-1951		*T. dicoccoides*	Turkey	No	AI	II
KU-1952		*T. dicoccoides*	Turkey	No	AI	II
KU-1953		*T. dicoccoides*	Turkey	No	AI	II
KU-1955		*T. dicoccoides*	Turkey	Yes*	AII non-del	II
KU-1959A		*T. dicoccoides*	Turkey	No	AI	II
KU-1959B		*T. dicoccoides*	Turkey	No	AI	II
KU-1972B		*T. dicoccoides*	Turkey	Yes*	AI	II
KU-1974		*T. dicoccoides*	Turkey	No	AI	II
KU-1976B		*T. dicoccoides*	Turkey	Yes*	AII non-del	II
KU-1978B		*T. dicoccoides*	Turkey	No	AI	II
KU-1991		*T. dicoccoides*	Turkey	No	AII non-del	II
KU-8536		*T. dicoccoides*	Iraq	Yes*	AI	Ic
KU-8537		*T. dicoccoides*	Iraq	No	AI	Ic
KU-8538		*T. dicoccoides*	Iraq	No	AI	Ic
KU-8539		*T. dicoccoides*	Iraq	No	AI	Ic
KU-8541		*T. dicoccoides*	Iraq	No	AI	Ic
KU-8736A		*T. dicoccoides*	Iraq	No	AI	Ic
KU-8736B		*T. dicoccoides*	Iraq	No	AI	Ic
KU-8737		*T. dicoccoides*	Iraq	Yes*	AI	Ic
KU-8804		*T. dicoccoides*	Iraq	No	AI	III
KU-8805		*T. dicoccoides*	Iraq	No	AI	III
KU-8806		*T. dicoccoides*	Iraq	No	AI	III
KU-8808		*T. dicoccoides*	Iraq	No	AI	III
KU-8809		*T. dicoccoides*	Iraq	No	AI	III
KU-8810		*T. dicoccoides*	Iraq	Yes*	AI	III
KU-8811		*T. dicoccoides*	Iraq	No	AI	III
KU-8812		*T. dicoccoides*	Iraq	No	AI	III
KU-8815		*T. dicoccoides*	Iraq	No	AI	III
KU-8816A		*T. dicoccoides*	Iraq	No	AI	III
KU-8816B		*T. dicoccoides*	Iraq	No	AI	III
KU-8817		*T. dicoccoides*	Iraq	No	AI	III
KU-8821A		*T. dicoccoides*	Iraq	Yes*	AI	Ib
KU-8821C		*T. dicoccoides*	Iraq	No	AI	Ib
KU-8915A		*T. dicoccoides*	Turkey	Yes*	AI	Ib
KU-8915B		*T. dicoccoides*	Turkey	No	AI	Ib
KU-8935		*T. dicoccoides*	Turkey	Yes*	AI	Ib
KU-8937B		*T. dicoccoides*	Turkey	No	AI	Ib
KU-8941		*T. dicoccoides*	Iran	Yes*	AI	Ic
KU-8942		*T. dicoccoides*	Iran	Yes*	AI	Ic
KU-8943		*T. dicoccoides*	Iran	Yes*	AI	Ic
KU-13441		*T. dicoccoides*	Israel	No	AII dic-del	-
KU-13442		*T. dicoccoides*	Israel	No	AII dic-del	-
KU-13444		*T. dicoccoides*	Israel	No	AII dic-del	-
KU-13445		*T. dicoccoides*	Israel	No	AII dic-del	-
KU-13446		*T. dicoccoides*	Israel	No	AII dic-del	-
KU-13447		*T. dicoccoides*	Israel	No	AI	-

KU-13448	*T. dicoccoides*	Israel	No	AI	-
KU-13449	*T. dicoccoides*	Israel	No	AII non-del	-
KU-13451	*T. dicoccoides*	Israel	No	AII non-del	-
KU-13452	*T. dicoccoides*	Israel	No	AII non-del	-
KU-13453	*T. dicoccoides*	Israel	No	AII non-del	-
KU-13454	*T. dicoccoides*	Israel	No	AI	-
KU-14401	*T. dicoccoides*	Israel	No	AI	IV
KU-14402	*T. dicoccoides*	Israel	No	AI	-
KU-14403	*T. dicoccoides*	Israel	No	AII non-del	IV
KU-14404	*T. dicoccoides*	Israel	Yes*	AI	-
KU-14405	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14406	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14407	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14408	*T. dicoccoides*	Israel	No	AI	-
KU-14409	*T. dicoccoides*	Israel	No	AI	-
KU-14410	*T. dicoccoides*	Israel	No	AI	-
KU-14411	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14412	*T. dicoccoides*	Israel	No	AI	-
KU-14413	*T. dicoccoides*	Israel	No	AI	-
KU-14414	*T. dicoccoides*	Israel	No	AI	-
KU-14415	*T. dicoccoides*	Israel	No	AI	-
KU-14417	*T. dicoccoides*	Israel	Yes	AII dic-del	V
KU-14418	*T. dicoccoides*	Israel	No	AII dic-del	-
KU-14419	*T. dicoccoides*	Israel	No	AII dic-del	V
KU-14420	*T. dicoccoides*	Israel	Yes	AII dic-del	-
KU-14421	*T. dicoccoides*	Israel	No	AII dic-del	-
KU-14422	*T. dicoccoides*	Israel	No	AII dic-del	-
KU-14423	*T. dicoccoides*	Israel	Yes	AII dic-del	-
KU-14424	*T. dicoccoides*	Israel	No	AII dic-del	-
KU-14425	*T. dicoccoides*	Israel	No	AII dic-del	-
KU-14426	*T. dicoccoides*	Israel	No	AII dic-del	-
KU-14427	*T. dicoccoides*	Israel	Yes	AII non-del	IV
KU-14428	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14429	*T. dicoccoides*	Israel	No	AII non-del	IV
KU-14430	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14431	*T. dicoccoides*	Israel	No	AI	-
KU-14432	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14434	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14435	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14436	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14437	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14438	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14439	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14440	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14441	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14442	*T. dicoccoides*	Israel	No	AI	-
KU-14443	*T. dicoccoides*	Israel	No	AI	IV
KU-14444	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14445	*T. dicoccoides*	Israel	No	AI	IV
KU-14446	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14447	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14448	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14449	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14450	*T. dicoccoides*	Israel	Yes*	AI	-
KU-14451	*T. dicoccoides*	Israel	No	AI	IV
KU-14452	*T. dicoccoides*	Israel	No	AI	-
KU-14453	*T. dicoccoides*	Israel	No	AI	IV
KU-14455	*T. dicoccoides*	Israel	No	AI	-
KU-14456	*T. dicoccoides*	Israel	No	AI	-
KU-14457	*T. dicoccoides*	Israel	No	AI	-
KU-14458	*T. dicoccoides*	Israel	No	AI	-
KU-14459	*T. dicoccoides*	Israel	No	AI	-
KU-14460	*T. dicoccoides*	Israel	No	AI	-

KU-14461	*T. dicoccoides*	Israel	No	AI	-
KU-14462	*T. dicoccoides*	Israel	No	AI	IV
KU-14464	*T. dicoccoides*	Israel	No	AI	IV
KU-14465	*T. dicoccoides*	Israel	No	AI	-
KU-14468	*T. dicoccoides*	Israel	Yes	AI	-
KU-14469	*T. dicoccoides*	Israel	No	AI	-
KU-14470	*T. dicoccoides*	Israel	No	AI	-
KU-14471	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14472	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14474	*T. dicoccoides*	Israel	No	AII dic-del	V
KU-14475	*T. dicoccoides*	Israel	No	AII dic-del	-
KU-14476	*T. dicoccoides*	Israel	No	AII dic-del	V
KU-14477	*T. dicoccoides*	Israel	No	AII dic-del	-
KU-14478	*T. dicoccoides*	Israel	No	AII dic-del	-
KU-14480	*T. dicoccoides*	Israel	No	AI	-
KU-14481	*T. dicoccoides*	Israel	No	AII dic-del	-
KU-14482	*T. dicoccoides*	Israel	No	AII dic-del	-
KU-14483	*T. dicoccoides*	Israel	No	AI	-
KU-14484	*T. dicoccoides*	Israel	No	AII dic-del	-
KU-14485	*T. dicoccoides*	Israel	No	AII dic-del	-
KU-14486	*T. dicoccoides*	Israel	No	AII dic-del	-
KU-14487	*T. dicoccoides*	Israel	No	AII dic-del	-
KU-14488	*T. dicoccoides*	Israel	No	AII dic-del	-
KU-14489	*T. dicoccoides*	Israel	No	AII dic-del	-
KU-14490	*T. dicoccoides*	Israel	No	AII non-del	IV
KU-14491	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14492	*T. dicoccoides*	Israel	No	AII non-del	IV
KU-14493	*T. dicoccoides*	Israel	Yes*	AII non-del	-
KU-14494	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14495	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14496	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14497	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14498	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14499	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14500	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14501	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14503	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14504	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14505	*T. dicoccoides*	Israel	No	AII non-del	IV
KU-14507	*T. dicoccoides*	Israel	No	AII dic-del	IV
KU-14509	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14510	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14511	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14512	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14514	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14516	*T. dicoccoides*	Israel	Yes	AII dic-del	-
KU-14517	*T. dicoccoides*	Israel	No	AII non-del	IV
KU-14518	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14519	*T. dicoccoides*	Israel	No	AII non-del	IV
KU-14520	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14521	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14522	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14523	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14524	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14525	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14526	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14527	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14528	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14529	*T. dicoccoides*	Israel	No	AII non-del	-
KU-14530	*T. dicoccoides*	Israel	No	AII dic-del	-
KU-14531	*T. dicoccoides*	Israel	Yes	AII ara-del	-
KU-14532	*T. dicoccoides*	Israel	No	AI	-
KU-112	*T. dicoccon*	China (India)	Yes*	AII non-del	-

KU-491	*T. dicoccon*	India	Yes	AII non-del	-
KU-492	*T. dicoccon*	India	Yes	AI	-
KU-493	*T. dicoccon*	India	No	AII non-del	-
KU-494	*T. dicoccon*	India	No	AII non-del	-
KU-495	*T. dicoccon*	India	Yes*	AII non-del	-
KU-496	*T. dicoccon*	India	No	AII non-del	-
KU-1023	*T. dicoccon*	Spain	Yes*	AI	-
KU-1056	*T. dicoccon*	Spain	No	AI	-
KU-1058	*T. dicoccon*	Spain	No	AI	-
KU-1061	*T. dicoccon*	Spain	No	AI	-
KU-1063a	*T. dicoccon*	Spain	No	AI	-
KU-1065	*T. dicoccon*	Spain	No	AI	-
KU-1071	*T. dicoccon*	Spain	Yes*	AI	-
KU-1102	*T. dicoccon*	Spain	No	AI	-
KU-1105	*T. dicoccon*	Spain	No	AI	-
KU-1108	*T. dicoccon*	Spain	No	AI	-
KU-1109	*T. dicoccon*	Spain	No	AI	-
KU-1113	*T. dicoccon*	Spain	Yes*	AI	-
KU-1123	*T. dicoccon*	Spain	No	AI	-
KU-1533	*T. dicoccon*	USSR	Yes	AII ara-del	-
KU-1538	*T. dicoccon*	USSR	Yes	AII ara-del	-
KU-1564	*T. dicoccon*	USSR	No	AI	-
KU-1582	*T. dicoccon*	USSR	No	AI	-
KU-3371	*T. dicoccon*	Iran	Yes	AII ara-del	-
KU-3722	*T. dicoccon*	Turkey	Yes*	AII non-del	-
KU-3723	*T. dicoccon*	Turkey	No	AII non-del	-
KU-4541	*T. dicoccon*	Iran	No	AI	-
KU-7301	*T. dicoccon*	Ethiopia	Yes*	AII non-del	-
KU-7303	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-7305	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-7307	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-7309	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-7311	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9001	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9003	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9005	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9007	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9011	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9013	*T. dicoccon*	Ethiopia	Yes*	AII non-del	-
KU-9015	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9017	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9021	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9023	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9025	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9027	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9029	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9031	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9763	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9765	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9767	*T. dicoccon*	Ethiopia	Yes*	AII non-del	-
KU-9769	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9771	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9773	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9777	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9779	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9781	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9783	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9785	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9787	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9789	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9791	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-9793	*T. dicoccon*	Ethiopia	No	AII non-del	-
KU-10490	*T. dicoccon*	Iran	Yes*	AI	-

KU-10492	*T. dicoccon*	Iran	No	AI	-
KU-10494	*T. dicoccon*	Iran	Yes*	AI	-
KU-10497	*T. dicoccon*	Iran	No	AI	-
KU-10500	*T. dicoccon*	Iran	Yes*	AI	-
KU-10501	*T. dicoccon*	Iran	No	AI	-
KU-10503	*T. dicoccon*	Iran	No	AI	-
CItr 7686	*T. dicoccon*	Russia	Yes*	AI	-
CItr 12213	*T. dicoccon*	India	Yes*	AII non-del	-
PI 94663	*T. dicoccon*	Germany	Yes*	AII ara-del	-
PI 11650	*T. dicoccon*	France	Yes*	AII non-del	-
PI 56234	*T. dicoccon*	Portugal	Yes*	AI	-
PI 57536	*T. dicoccon*	Ukraine	Yes*	AII non-del	-
PI 94618	*T. dicoccon*	Belarus	Yes*	AI	-
PI 94633	*T. dicoccon*	Morocco	Yes*	AII ara-del	-
PI 94664	*T. dicoccon*	Saudi Arabia	Yes*	AII non-del	-
PI 94671	*T. dicoccon*	Afghanistan	Yes*	AII non-del	-
PI 94682	*T. dicoccon*	Greece	Yes*	AI	-
PI 182743	*T. dicoccon*	Turkey	Yes*	AII non-del	-
PI 254177	*T. dicoccon*	Iran	Yes*	AII ara-del	-
PI 254189	*T. dicoccon*	Georgia	Yes*	AII ara-del	-
PI 272533	*T. dicoccon*	Hungary	Yes*	AII ara-del	-
PI 277677	*T. dicoccon*	Spain	Yes*	AI	-
PI 286061	*T. dicoccon*	Poland	Yes*	AI	-
PI 306534	*T. dicoccon*	Romania	Yes*	AII non-del	-
PI 352361	*T. dicoccon*	Italy	Yes*	AI	-
PI 352367	*T. dicoccon*	Ancient Palestine	Yes*	AII non-del	-
PI 352369	*T. dicoccon*	Czech Republic	Yes*	AI	-
PI 355488	*T. dicoccon*	Italy	Yes*	AI	-
PI 355496	*T. dicoccon*	Ancient Palestine	Yes*	AII non-del	-
PI 355497	*T. dicoccon*	USSR	Yes*	AII non-del	-
PI 355498	*T. dicoccon*	Syria	Yes*	AII non-del	-
PI 355502	*T. dicoccon*	USSR	Yes*	AII non-del	-
PI 361833	*T. dicoccon*	Denmark	Yes*	AII non-del	-
PI 377658	*T. dicoccon*	Former Yugoslavia	Yes*	AI	-
PI 377672	*T. dicoccon*	Former Yugoslavia	Yes*	AI	-
PI 434993	*T. dicoccon*	Montenegro	Yes*	AI	-
PI 434995	*T. dicoccon*	Bosnia and Herzegovina	Yes*	AI	-
PI 470739	*T. dicoccon*	Turkey	Yes*	AI	-
PI 532302	*T. dicoccon*	Oman	Yes*	AII non-del	-
KU-190-2	*T. karamyschevii*	USSR	Yes	AI	-
KU-191	*T. karamyschevii*	-	Yes	AI	-
KU-145	*T. ispahanicum*	Iran	Yes	AII ara-del	-
KU-4580	*T. ispahanicum*	Iran	Yes	AII ara-del	-
KU-128-2	*T. durum*	China	No	AI	-
KU-1156	*T. durum*	Turkey	No	AI	-
KU-1354	*T. durum*	Greece	Yes*	AI	-
KU-3654	*T. durum*	Egypt	Yes*	AI	-
KU-3658	*T. durum*	Egypt	Yes*	AI	-
KU-3661	*T. durum*	Jordan	Yes*	AI	-
KU-3673	*T. durum*	Jordan	Yes*	AI	-
KU-3674	*T. durum*	Jordan	Yes*	AI	-
KU-3675	*T. durum*	Lebanon	Yes*	AI	-
KU-3678	*T. durum*	Syria	No	AI	-
KU-3680	*T. durum*	Syria	No	AI	-
KU-3685	*T. durum*	Syria	No	AI	-
KU-3688	*T. durum*	Turkey	No	AI	-
KU-3697	*T. durum*	Turkey	No	AI	-
KU-3706	*T. durum*	Turkey	No	AI	-
KU-3714	*T. durum*	Turkey	No	AI	-
KU-3738	*T. durum*	Italy	Yes*	AI	-
KU-7342	*T. durum*	Afghanistan	No	AI	-
KU-7371	*T. durum*	Ethiopia	Yes*	AI	-
KU-9169	*T. durum*	Ethiopia	Yes*	AI	-

KU-9246	*T. durum*	Ethiopia	Yes*	AI	-
KU-9339	*T. durum*	Ethiopia	Yes*	AI	-
KU-9415	*T. durum*	Ethiopia	Yes*	AI	-
KU-9695	*T. durum*	Ethiopia	Yes*	AI	-
KU-9745	*T. durum*	Ethiopia	Yes*	AI	-
KU-10010	*T. durum*	Iraq	No	AI	-
KU-10042	*T. durum*	Iraq	Yes*	AI	-
KU-10077	*T. durum*	Iraq	Yes*	AI	-
KU-10090	*T. durum*	Iraq	No	AI	-
KU-10169	*T. durum*	Iraq	No	AI	-
KU-10466	*T. durum*	Iran	Yes*	AI	-
KU-10508	*T. durum*	Iran	No	AI	-
KU-10513	*T. durum*	Iran	Yes*	AI	-
KU-11342	*T. durum*	Afghanistan	No	AI	-
KU-11731	*T. durum*	Greece	Yes*	AI	-
KU-11811	*T. durum*	Greece	Yes*	AI	-
KU-11820	*T. durum*	Greece	Yes*	AI	-
KU-11836	*T. durum*	Greece	No	AI	-
CItr 1471	*T. durum*	Algeria	Yes*	AI	-
CItr 1515	*T. durum*	Russian Federation	No	AI	-
CItr 2468	*T. durum*	Germany	No	AI	-
CItr 6870	*T. durum*	Tunisia	Yes*	AI	-
CItr 6879	*T. durum*	Morocco	Yes*	AI	-
CItr 6888	*T. durum*	Italy	Yes*	AI	-
CItr 14802	*T. durum*	Eritrea	Yes*	AI	-
CItr 14810	*T. durum*	Eritrea	No	AI	-
CItr 15065	*T. durum*	Afghanistan	No	AI	-
CItr 15450	*T. durum*	Tunisia	Yes*	AI	-
PI 4789	*T. durum*	Spain	Yes*	AI	-
PI 5380	*T. durum*	Algeria	No	AII non-del	-
PI 5639	*T. durum*	Kazakhstan	No	AI	-
PI 6020	*T. durum*	Ukraine	No	AI	-
PI 8898	*T. durum*	India	Yes*	AI	-
PI 24491	*T. durum*	Uzbekistan	No	AI	-
PI 40938	*T. durum*	Pakistan	No	AI	-
PI 40939	*T. durum*	Pakistan	No	AI	-
PI 40940	*T. durum*	Pakistan	Yes*	AI	-
PI 41012	*T. durum*	India	No	AI	-
PI 47889	*T. durum*	Spain	Yes*	AI	-
PI 52503	*T. durum*	Israel	Yes*	AI	-
PI 54432	*T. durum*	Libya	Yes*	AI	-
PI 57189	*T. durum*	Azerbaijan	Yes*	AI	-
PI 60727	*T. durum*	Egypt	Yes*	AI	-
PI 60734	*T. durum*	Egypt	No	AI	-
PI 60741	*T. durum*	Egypt	Yes*	AI	-
PI 61103	*T. durum*	Russian Federation	No	AI	-
PI 61111	*T. durum*	Georgia	No	AI	-
PI 61114	*T. durum*	Iran	No	AI	-
PI 61123	*T. durum*	Kazakhstan	No	AI	-
PI 61127	*T. durum*	Kyrgyzstan	No	AI	-
PI 61185	*T. durum*	Moldova	Yes*	AI	-
PI 73366	*T. durum*	Azerbaijan	No	AI	-
PI 78810	*T. durum*	Georgia	No	AI	-
PI 94684	*T. durum*	Armenia	Yes*	AI	-
PI 94701	*T. durum*	Ancient Palestine	No	AI	-
PI 113953	*T. durum*	Jordan	No	AI	-
PI 115515	*T. durum*	India	Yes*	AI	-
PI 134442	*T. durum*	India	No	AI	-
PI 134958	*T. durum*	Portugal	Yes*	AI	-
PI 136573	*T. durum*	Spain	Yes*	AI	-
PI 172544	*T. durum*	Turkey	Yes*	AI	-
PI 174628	*T. durum*	Italy	Yes*	AI	-
PI 174662	*T. durum*	France	No	AI	-

PI 182667	*T. durum*	Lebanon	Yes*	AI	-
PI 182669	*T. durum*	Lebanon	Yes*	AI	-
PI 183909	*T. durum*	Saudi Arabia	Yes*	AI	-
PI 184170	*T. durum*	Bosnia and Herzegovina	No	AII non-del	-
PI 185233	*T. durum*	United Kingdom	Yes*	AI	-
PI 191103	*T. durum*	Spain	Yes*	AI	-
PI 191194	*T. durum*	Spain	No	AI	-
PI 191411	*T. durum*	Morocco	No	AI	-
PI 192655	*T. durum*	Morocco	No	AI	-
PI 192843	*T. durum*	Portugal	Yes*	AI	-
PI 204050	*T. durum*	Portugal	No	AII non-del	-
PI 210954	*T. durum*	Cyprus	Yes*	AI	-
PI 210960	*T. durum*	Cyprus	No	AI	-
PI 221409	*T. durum*	Serbia	Yes*	AII non-del	-
PI 234382	*T. durum*	Jordan	No	AI	-
PI 237630	*T. durum*	Cyprus	Yes*	AI	-
PI 244061	*T. durum*	Yemen	Yes*	GS-105	-
PI 261823	*T. durum*	Saudi Arabia	No	AI	-
PI 264959	*T. durum*	Croatia	No	AI	-
PI 265010	*T. durum*	Bosnia and Herzegovina	No	AI	-
PI 274668	*T. durum*	Poland	Yes*	AI	-
PI 277126	*T. durum*	Bulgaria	Yes*	AI	-
PI 278376	*T. durum*	Malta	Yes*	AI	-
PI 290495	*T. durum*	Hungary	Yes*	AI	-
PI 290503	*T. durum*	Hungary	No	AI	-
PI 292031	*T. durum*	Israel	Yes*	AI	-
PI 295010	*T. durum*	Bulgaria	No	AI	-
PI 345442	*T. durum*	Croatia	No	AII non-del	-
PI 347142	*T. durum*	Afghanistan	No	AI	-
PI 352385	*T. durum*	Switzerland	Yes*	AI	-
PI 352459	*T. durum*	France	Yes*	AI	-
PI 361746	*T. durum*	Denmark	Yes*	AI	-
PI 367195	*T. durum*	Afghanistan	No	AI	-
PI 374658	*T. durum*	Macedonia	Yes*	AII non-del	-
PI 376495	*T. durum*	Romania	Yes*	AI	-
PI 382046	*T. durum*	Iran	No	AII non-del	-
PI 405906	*T. durum*	Macedonia	Yes*	AII non-del	-
PI 429320	*T. durum*	Yemen	No	AI	-
PI 435025	*T. durum*	Montenegro	Yes*	AII non-del	-
PI 470763	*T. durum*	Italy	Yes*	AI	-
PI 532281	*T. durum*	Oman	Yes*	AI	-
PI 532291	*T. durum*	Oman	Yes*	AI	-
PI 654182	*T. durum*	Tajikistan	No	AI	-
KU-9202	*T. turgidum*	Ethiopia	Yes*	AI	-
KU-9283	*T. turgidum*	Ethiopia	Yes*	AI	-
KU-9302	*T. turgidum*	Ethiopia	Yes*	AI	-
KU-9416	*T. turgidum*	Ethiopia	Yes*	AI	-
KU-9607	*T. turgidum*	Ethiopia	Yes*	AI	-
KU-9889	*T. turgidum*	Ethiopia	Yes*	AI	-
PI 57661	*T. turgidum*	Egypt	No	AI	-
PI 94689	*T. turgidum*	Armenia	No	AI	-
PI 134946	*T. turgidum*	Portugal	No	AI	-
PI 134951	*T. turgidum*	Portugal	No	AI	-
PI 166496	*T. turgidum*	Turkey	No	AII non-del	-
PI 167867	*T. turgidum*	Turkey	No	AI	-
PI 191104	*T. turgidum*	Spain	No	AII non-del	-
PI 208912	*T. turgidum*	Iraq	No	AI	-
PI 347134	*T. turgidum*	Afghanistan	No	AI	-
PI 347137	*T. turgidum*	Afghanistan	No	AI	-
PI 349060	*T. turgidum*	Azerbaijan	No	AI	-
PI 372447	*T. turgidum*	Cyprus	No	AI	-
PI 372450	*T. turgidum*	Cyprus	No	AI	-
PI 374618	*T. turgidum*	Macedonia	No	AII non-del	-

PI 374655	*T. turgidum*	Macedonia	No	AI	-
PI 542679	*T. turgidum*	Algeria	No	AII non-del	-
PI 623927	*T. turgidum*	Iran	No	AII non-del	-
KU-7345	*T. polonicum*	Ethiopia	Yes*	AI	-
KU-7346	*T. polonicum*	Afghanistan	No	AI	-
KU-9895	*T. polonicum*	Ethiopia	Yes*	AI	-
PI 56261	*T. polonicum*	Portugal	No	AI	-
PI 167622	*T. polonicum*	Turkey	No	AI	-
PI 208911	*T. polonicum*	Iraq	No	AI	-
PI 223171	*T. polonicum*	Jordan	No	AI	-
PI 225334	*T. polonicum*	Iran	No	AI	-
PI 254214	*T. polonicum*	India	No	AI	-
PI 290512	*T. polonicum*	Portugal	No	AI	-
PI 352488	*T. polonicum*	Italy	No	AI	-
KU-3724	*T. carthlicum*	Turkey	No	AI	-
PI 61102	*T. carthlicum*	Georgia	Yes*	AI	-
PI 70738	*T. carthlicum*	Iraq	Yes*	AI	-
PI 94748	*T. carthlicum*	Georgia	Yes*	AI	-
PI 182471	*T. carthlicum*	Turkey	No	AI	-
PI 283887	*T. carthlicum*	Iran	Yes*	AI	-
PI 470730	*T. carthlicum*	Turkey	Yes*	AI	-
PI 585017	*T. carthlicum*	Georgia	No	AI	-
KU-3368	*T. turanicum*	Iran	No	AI	-
PI 10391	*T. turanicum*	Egypt	Yes*	AI	-
PI 113392	*T. turanicum*	Iran	Yes*	AI	-
PI 113393	*T. turanicum*	Iraq	Yes*	AI	-
PI 124494	*T. turanicum*	India	Yes*	AI	-
PI 127106	*T. turanicum*	Afghanistan	Yes*	AI	-
PI 166308	*T. turanicum*	Turkey	Yes*	AI	-
PI 166450	*T. turanicum*	Turkey	No	AI	-
PI 337643	*T. turanicum*	Afghanistan	No	AI	-
PI 352514	*T. turanicum*	Azerbaijan	Yes*	AI	-
PI 537992	*T. turanicum*	Turkey	No	AI	-
PI 624893	*T. turanicum*	Iran	No	AI	-
PI 625187	*T. turanicum*	Iran	No	AI	-
KU-9049	*T. aethiopicum*	Ethiopia	Yes*	AI	-
KU-9083	*T. aethiopicum*	Ethiopia	No	AI	-
KU-9097	*T. aethiopicum*	Ethipoia	No	AI	-
KU-9133	*T. aethiopicum*	Ethiopia	No	AI	-
KU-9141	*T. aethiopicum*	Ethiopia	No	AI	-
KU-9228	*T. aethiopicum*	Ethiopia	Yes*	AI	-
KU-9269	*T. aethiopicum*	Ethiopia	No	AI	-
KU-9371	*T. aethiopicum*	Ethiopia	Yes*	AI	-
KU-9393	*T. aethiopicum*	Ethiopia	No	AI	-
KU-9414	*T. aethiopicum*	Ethiopia	No	AI	-
KU-9427	*T. aethiopicum*	Ethiopia	Yes*	AI	-
KU-9525	*T. aethiopicum*	Ethiopia	No	AI	-
KU-9533	*T. aethiopicum*	Ethiopia	No	AI	-
KU-9541	*T. aethiopicum*	Ethiopia	No	AI	-
KU-9545	*T. aethiopicum*	Ethiopia	No	AI	-
KU-9553	*T. aethiopicum*	Ethiopia	No	AI	-
KU-9565	*T. aethiopicum*	Ethiopia	No	AI	-
KU-9573	*T. aethiopicum*	Ethiopia	Yes*	AI	-
KU-9577	*T. aethiopicum*	Ethiopia	No	AI	-
KU-9585	*T. aethiopicum*	Ethiopia	No	AI	-
KU-9601	*T. aethiopicum*	Ethiopia	No	AI	-
KU-146	*T. pyramidare*	-	Yes	GS-105	-
KU-9882	*T. pyramidare*	Ethiopia	Yes	AI	-
KU-1903	*T. araraticum*	USSR (Armenia)	No	AII ara-del	-
KU-1909A	*T. araraticum*	USSR (Armenia)	No	AII ara-del	-
KU-1913	*T. araraticum*	USSR	No	AII ara-del	-
KU-1914	*T. araraticum*	Armenia	No	AII ara-del	-
KU-1925	*T. araraticum*	Turkey	No	AII ara-del	-

KU-1929	*T. araraticum*	Turkey	No	AII ara-del	-
KU-1933	*T. araraticum*	Turkey	No	AII ara-del	-
KU-1943	*T. araraticum*	Turkey	Yes	AII non-del	-
KU-1958	*T. araraticum*	Turkey	No	AII ara-del	-
KU-1964	*T. araraticum*	Turkey	No	AII ara-del	-
KU-1969	*T. araraticum*	Turkey	No	AII ara-del	-
KU-1978A	*T. araraticum*	Turkey	No	AII ara-del	-
KU-1982	*T. araraticum*	Turkey	No	AII ara-del	-
KU-1990	*T. araraticum*	Turkey	No	AII non-del	-
KU-8454	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8468	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8475	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8479	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8488	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8492	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8498	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8506	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8514	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8528A	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8545	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8549	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8561	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8567	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8593	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8598	*T. araraticum*	Iraq	Yes	AII ara-del	-
KU-8602	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8610	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8619	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8625	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8633	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8642	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8656	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8662	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8671	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8675	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8683	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8690	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8697	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8701	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8707	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8711	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8714B	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8718B	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8723	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8727	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8733	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8739	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8760	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8774	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8779	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8783	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8789	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8795	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8799B	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8819	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8824A	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8827	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8831	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8858	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8863	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8868	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8872	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8876	*T. araraticum*	Iraq	No	AII ara-del	-

KU-8880	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8885	*T. araraticum*	Iraq	No	AII ara-del	-
KU-1937	*T. araraticum*	Turkey	Yes	AII ara-del	-
KU-1983	*T. araraticum*	Turkey	Yes	AII ara-del	-
KU-8459	*T. araraticum*	Iraq	Yes	AII ara-del	-
KU-8620	*T. araraticum*	Iraq	Yes	AII ara-del	-
KU-8754	*T. araraticum*	Iraq	Yes	AII ara-del	-
KU-8913	*T. araraticum*	Turkey	Yes	AII ara-del	-
KU-8944	*T. araraticum*	Iran	Yes	AII ara-del	-
KU-8948	*T. araraticum*	Iran	Yes	AII ara-del	-
KU-8889	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8893	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8909	*T. araraticum*	Turkey	No	AII ara-del	-
KU-8914	*T. araraticum*	Turkey	No	AII ara-del	-
KU-8920	*T. araraticum*	Turkey	No	AII ara-del	-
KU-8926	*T. araraticum*	Turkey	No	AII ara-del	-
KU-8934	*T. araraticum*	Turkey	No	AII ara-del	-
KU-8478	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8731	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8802	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8890	*T. araraticum*	Iraq	No	AII ara-del	-
KU-8940	*T. araraticum*	Turkey	No	AII ara-del	-
KU-8947	*T. araraticum*	Iran	No	AII ara-del	-
IG 46247	*T. araraticum*	Turkey	No	AII ara-del	-
IG 113296	*T. araraticum*	Iran	No	AII ara-del	-
IG 116164	*T. araraticum*	Turkey	No	AII ara-del	-
IG 116165	*T. araraticum*	Turkey	No	AII ara-del	-
IG 116166	*T. araraticum*	Turkey	No	AII ara-del	-
IG 116168	*T. araraticum*	Turkey	No	AII ara-del	-
IG 116169	*T. araraticum*	Turkey	No	AII ara-del	-
IG 116170	*T. araraticum*	Turkey	No	AII ara-del	-
IG 116177	*T. araraticum*	Turkey	Yes	AII non-del	-
IG 117891	*T. araraticum*	Syria	No	AII ara-del	-
IG 117895	*T. araraticum*	Syria	No	AII ara-del	-
IG 119456	*T. araraticum*	Syria	No	AII ara-del	-
KU-107-2	*T. timopheevii*	-	Yes	AII ara-del	-
KU-107-3	*T. timopheevii*	-	Yes	AII ara-del	-
KU-107-4	*T. timopheevii*	USSR	Yes	AII ara-del	-
KU-107-5	*T. timopheevii*	Turkey	Yes	AII ara-del	-
KU-1819	*T. timopheevii*	-	Yes	AII ara-del	-

* the sequences date were our prebious study (Takenaka and Kawahara 2012)

** typed by Özkan *et al.* (2011)